Department of Health Red Hill Geology/Hydrogeology – Groundwater Flow Assessment and Proposed Investigations

Presented by:

Hawaii Department of Health,
Safe Drinking Water Branch

Presented to:

The Red Hill Groundwater Modeling Working Group

July 31, 2019; San Francisco, Ca

Department of Health
DOH Evaluation of Groundwater Flow Moanualua/Red Hill/Halawa Region

Overview

- DOH concerns
- Conceptual models of groundwater flow
- Indicators/Controls of groundwater flow paths
  - Groundwater elevation gradient
  - Groundwater chemistry gradients
  - Geology
- Conclusions

Why is DOH Concerned?

- Groundwater/source water protection is a DOH responsibility
  - Safe Drinking Water Act
    - Assessment of contamination risk to public drinking water supplies
  - Resource Conservation and Recovery Act
    - Regulation of underground storage tanks
- Red Hill Administrative Order on Consent
  - Important decisions dependent on proper characterization of the groundwater flow paths
    - Tank upgrade alternatives
    - Contaminant fate and transport evaluations
    - Groundwater Protection Plan responses
- In some critical areas the model does not currently appear to align with measured data

Measured Parameters that Relate to Groundwater Flow Paths

- Groundwater elevation
  - Estimate ground flow paths by defining gradient
  - Measured quarterly and continuously by the USGS
- Groundwater chemistry
  - Concentration gradient based on known source location
  - May be modified during travel along a flow path
  - Some key parameters measured regularly
- Geologic formations
  - Controls groundwater flow paths
  - Groundwater takes the least obstructed path along a gradient

Conceptual models of Groundwater Flow in Southeast Oahu

- Mauka to Makai
  - Prevailing conceptual model
  - Used by numerous researchers
    - e.g. Hunt (1996)
    - Whittier et al. (2004)
  - Is it consistent with recently acquired data?
- Honolulu to Pearl Harbor
  - Pondered by Wentworth (1942)
  - Stated by Mink (1980)

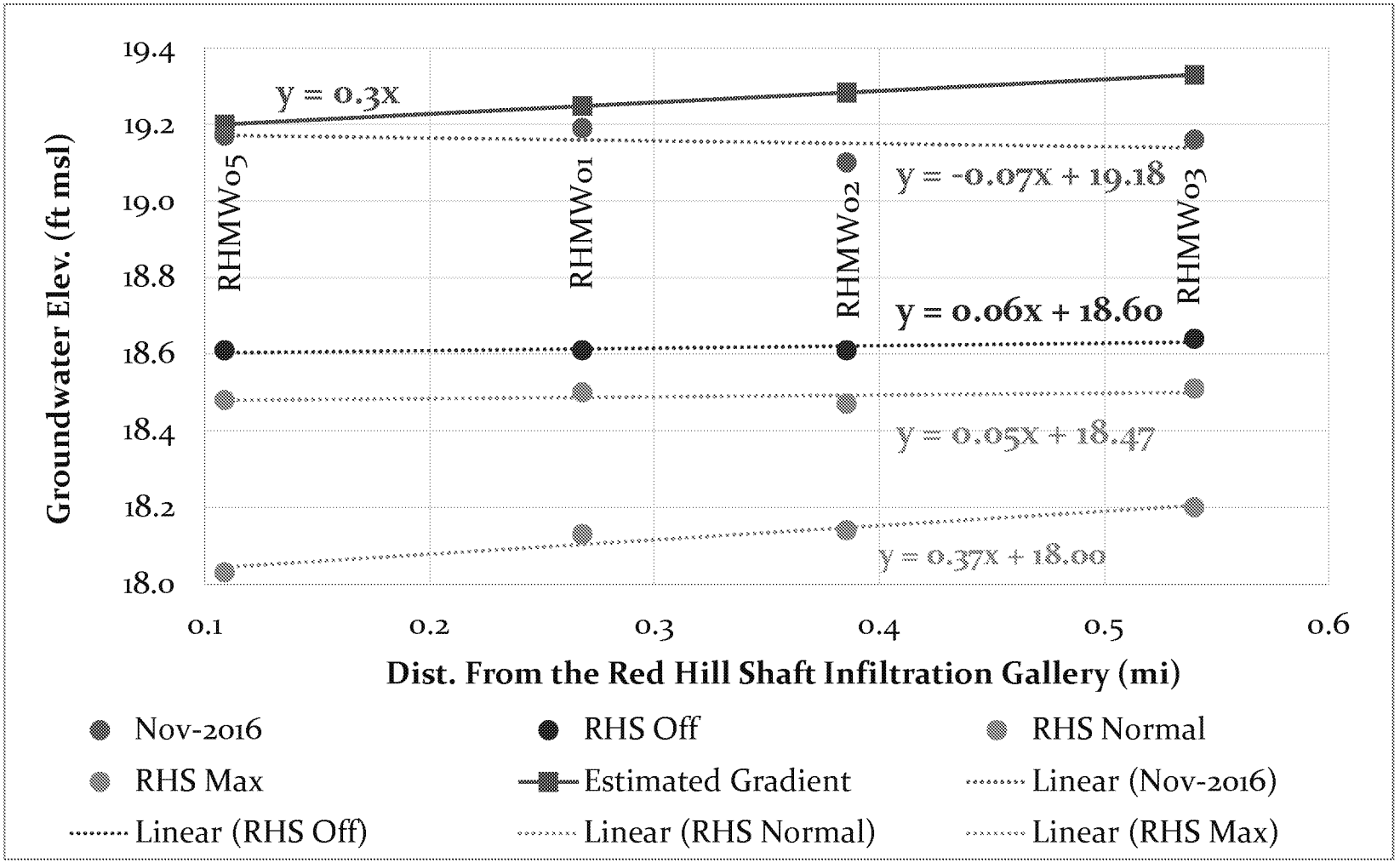
Measured and Modeled Parameters

- Groundwater Gradient

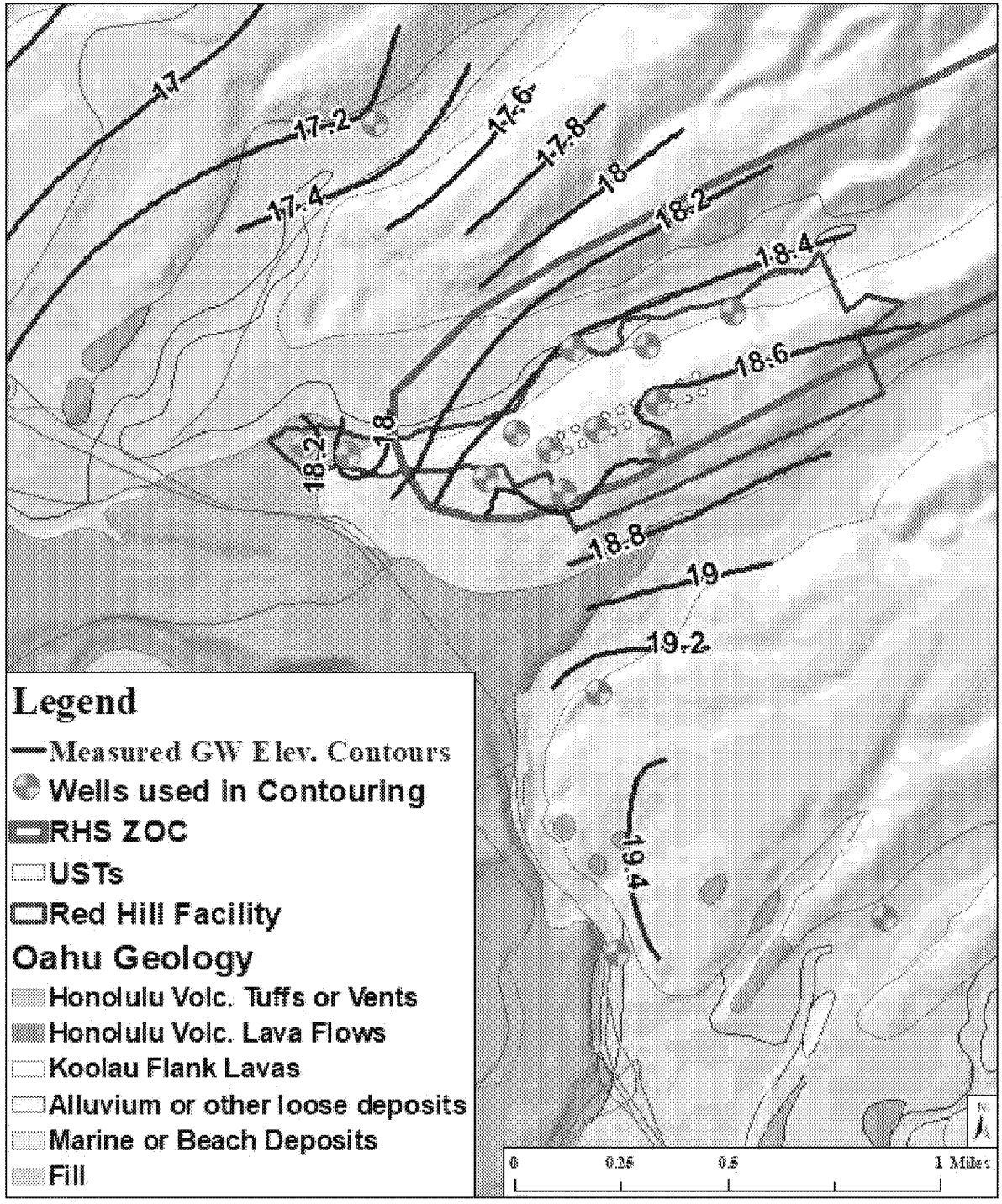
Groundwater Gradients

- Baseline gradient Red Hill Shaft based on the modeled zone of contribution (ZOC) as DOH currently understands it is currently modeled
- Some estimated values derived from ZOC
  - Recharge 5.8 mgd
  - Width – 2,800 ft
  - Thickness – 800 ft
  - K = 2,000 ft/d
  - Gradient ~ 0.3 ft/mi
    - Minimum gradient for natural conditions
    - Assumes uniform flow across entire width and thickness
    - Would steepen near pumping center
    - Would steepen as pumping increases (some consistency with model)
  - The major concern is whether or not the measured data supports mauka to makai flow

Groundwater Gradients & Aquifer Response to Changes in Pumping



- Gradient much less than 0.3 ft/mi
- No appreciable increase between no-pumping and "business as usual"
- Modeled and measured must match using reasonable hydraulic parameter values and geologic structure distribution



Groundwater Elevation Contours Modeled vs Measured

- Modeled –
  - Groundwater Protection Considerations Report (2018)
    - DOH acknowledges that much work has been done since
  - Gradient ~2 ft/mi going down axis of Red Hill Ridge
  - The modeled gradient would be easily measured
- Measured
  - From Conceptual Site Model Report (2018) Figure 6-10
  - Most pronounced gradient is to the northwest
  - In absence of a barrier groundwater will flow to the northwest
- Modeled vs measured
  - Risk implications very different

Measured and Modeled Parameters

- Groundwater Gradient
- Groundwater chemistry gradients
  - May indicate a component of groundwater flow to the northwest
  - When the Red Hill Shaft is off for an extended period

Dissolved Oxygen

- Modified by natural attenuation of fuel hydrocarbons
- Utility as a natural groundwater tracer
  - But only if we properly define "Normal" (i.e. background DO)

Background Dissolved Oxygen Concentration

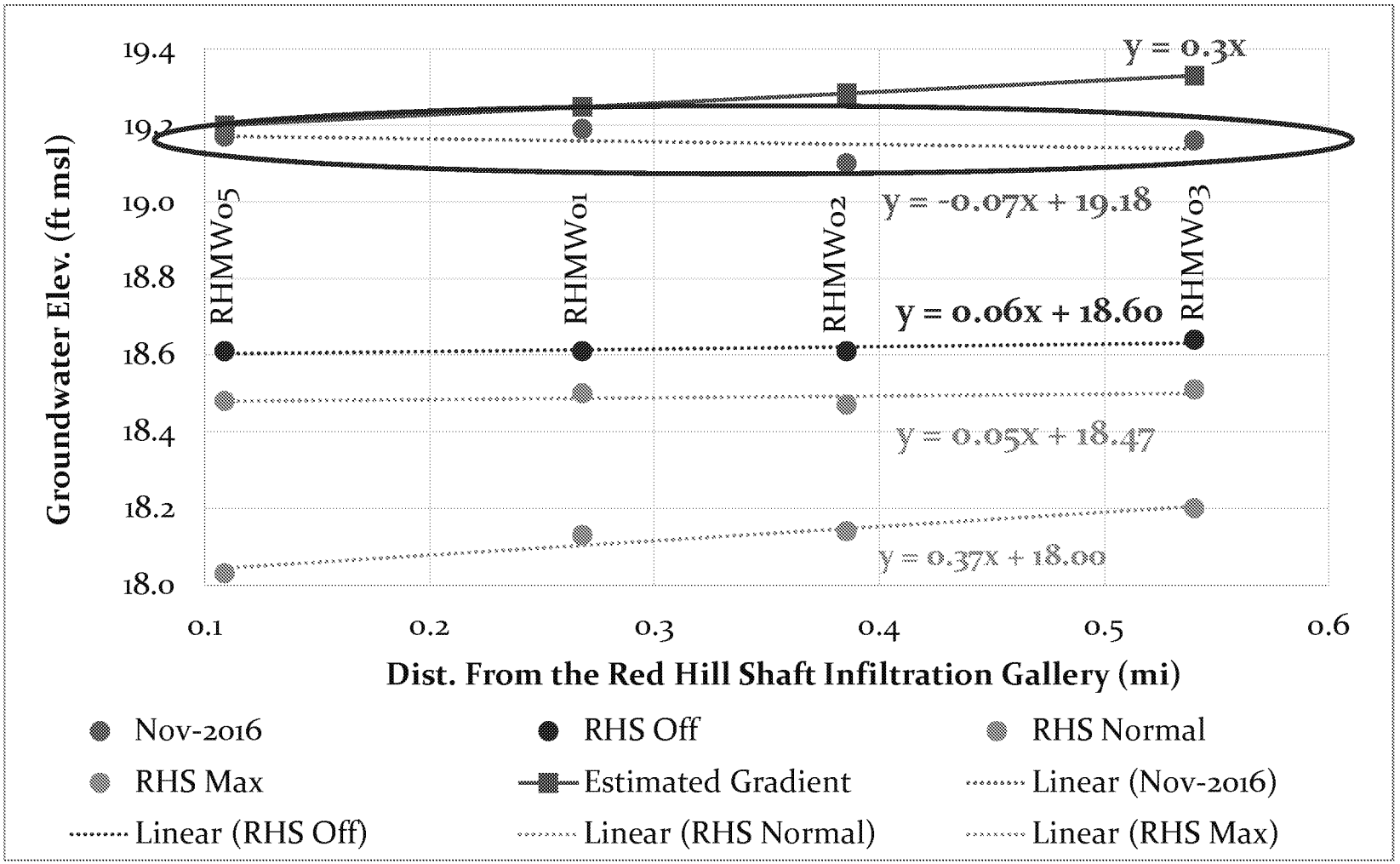
Table 2-5: Dissolved Oxygen Concentrations at Select Red Hill Wells vs. Monitoring Wells on O'ahu (Hunt Jr. 2004)

Well	DO Concentration (mg/L)			Notes
	Minimum	Maximum	Median	
RHMW04	4.62	9.9	8.36	—
RHMW05	5.32	9.7	8.29	—
RHMW06	3.26	7.77	6.28	Increasing trend with time, see Section 2.6 for discussion
RHMW07	0.18	5.18	2.63	Increasing trend with time, see Section 2.6 for discussion
RHMW08	3.12	6.16	4.46	Increasing trend with time, see Section 2.6 for discussion
RHMW09	6.1	9.06	8.38	—
RHMW10	6.22	9.31	8.03	—
USGS O'ahu Monitoring Wells	4.7	7.6	6.8	— **Influenced by agriculture**

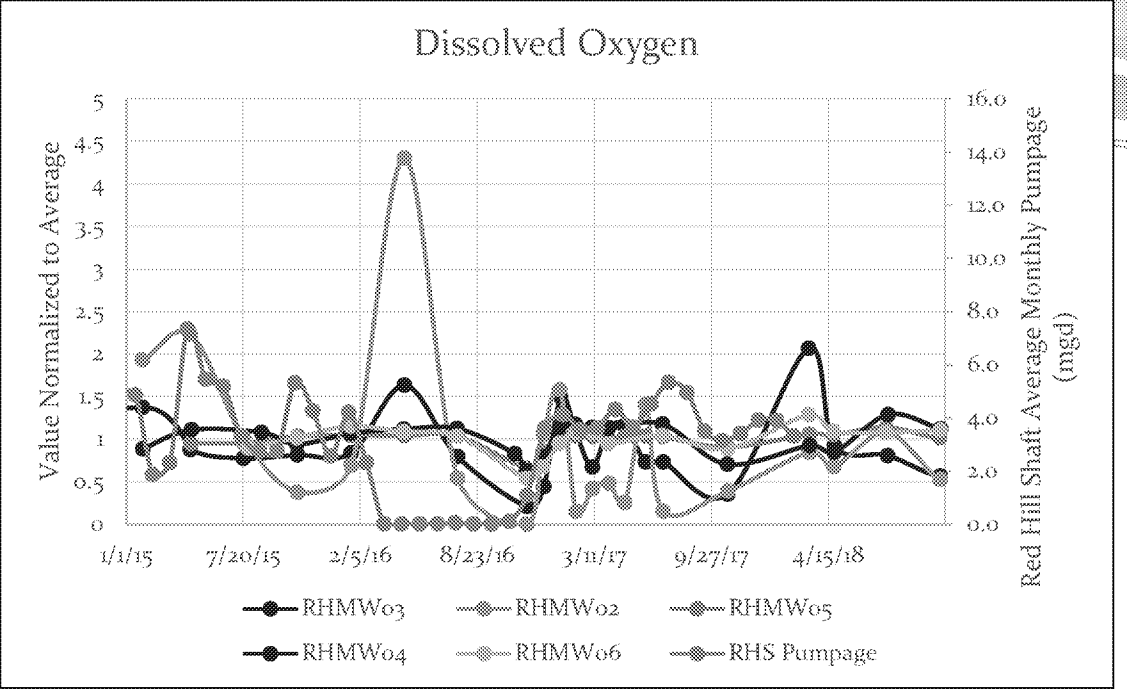
Table from the June 2019 revision to the Red Hill Conceptual Site Model Report

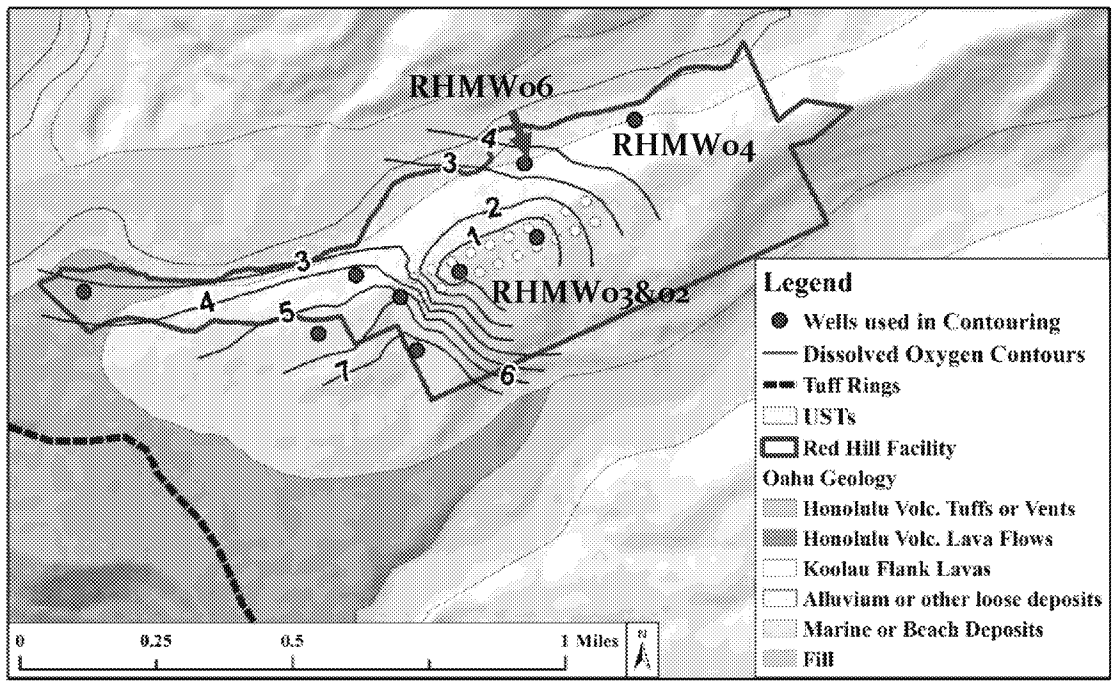
It appears 8.3 mg/L is a reasonable background DO concentration for Red Hill

Nov. 18, 2016 Groundwater Gradient



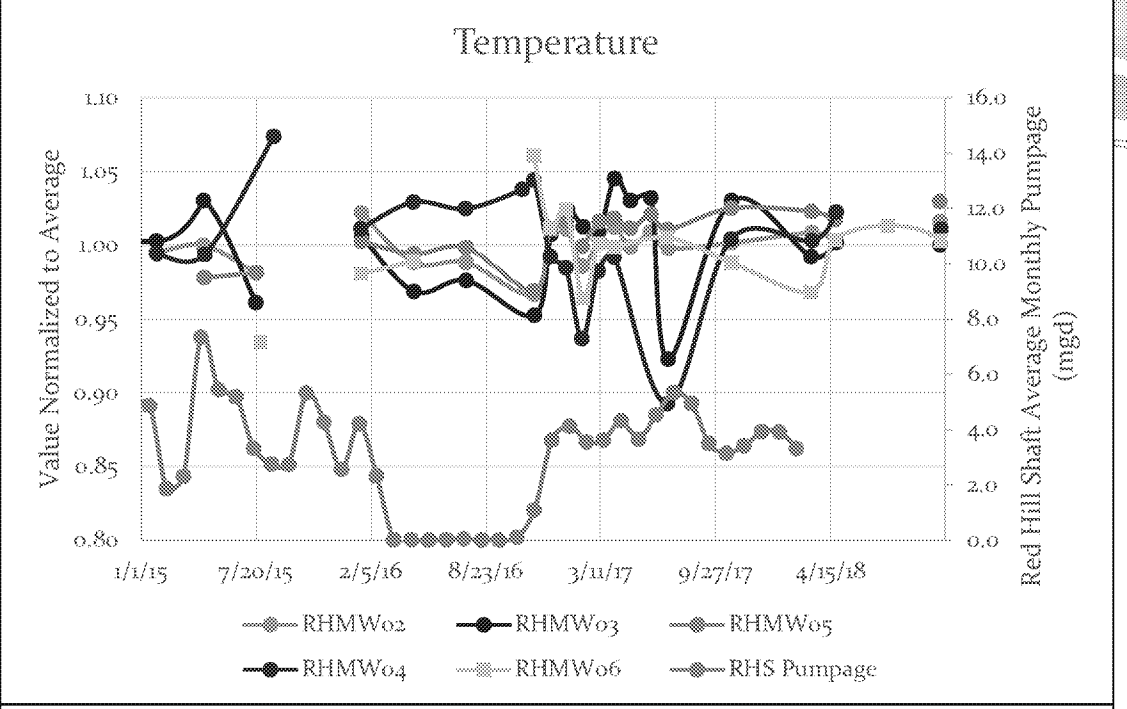
An apparent reverse gradient was measured on 11/18/16.
Is there any evidence that this is nothing more than measurement uncertainty?

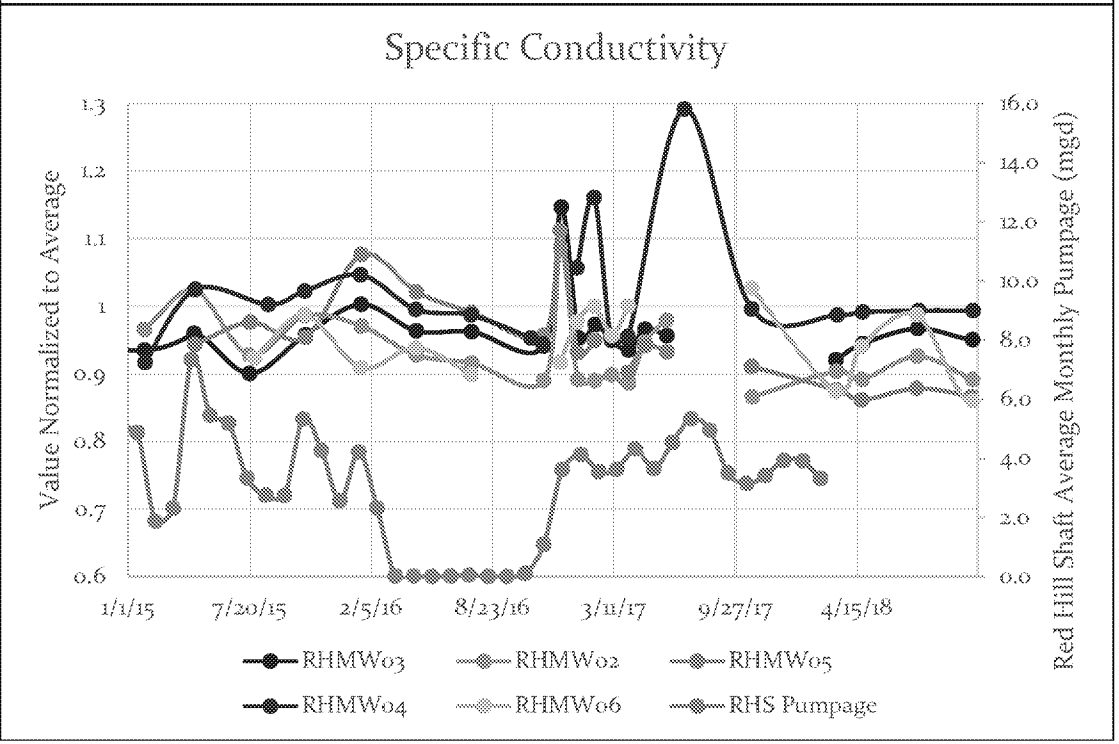




Water Quality Parameter Trends During Red Hill Shaft Shutdown

- Dissolved Oxygen
  - Normalized to average values
  - Initial increase at RHMW02,03
  - Then decrease
  - Others decrease across the board including RHMW04 and RHMW06
- Spatial distribution Nov. 2016
  - RHMW02/03 lowest (of course)
  - RHMW04 depleted in oxygen relative to historical values
- The DO depletion at RHMW04 consistent with the reverse gradient measured beneath the ridge





Water Quality Parameter Trends During Red Hill Shaft Shutdown

- Temperature
  - Decrease at RHMW02,03, &05
    - RHMW03 consistently the warmest well
  - Increase at RHMW04 & 06
  - Increase in temperature at RHMW04/06 consistent with flow to the northwest
- Specific Conductivity
  - Trend toward freshening at all wells
- Three routinely monitored parameters showed response to Red Hill Shaft shutdown
  - Two, DO and Temperature, are consistent with groundwater flow from RHMW02/03 to northwest wells

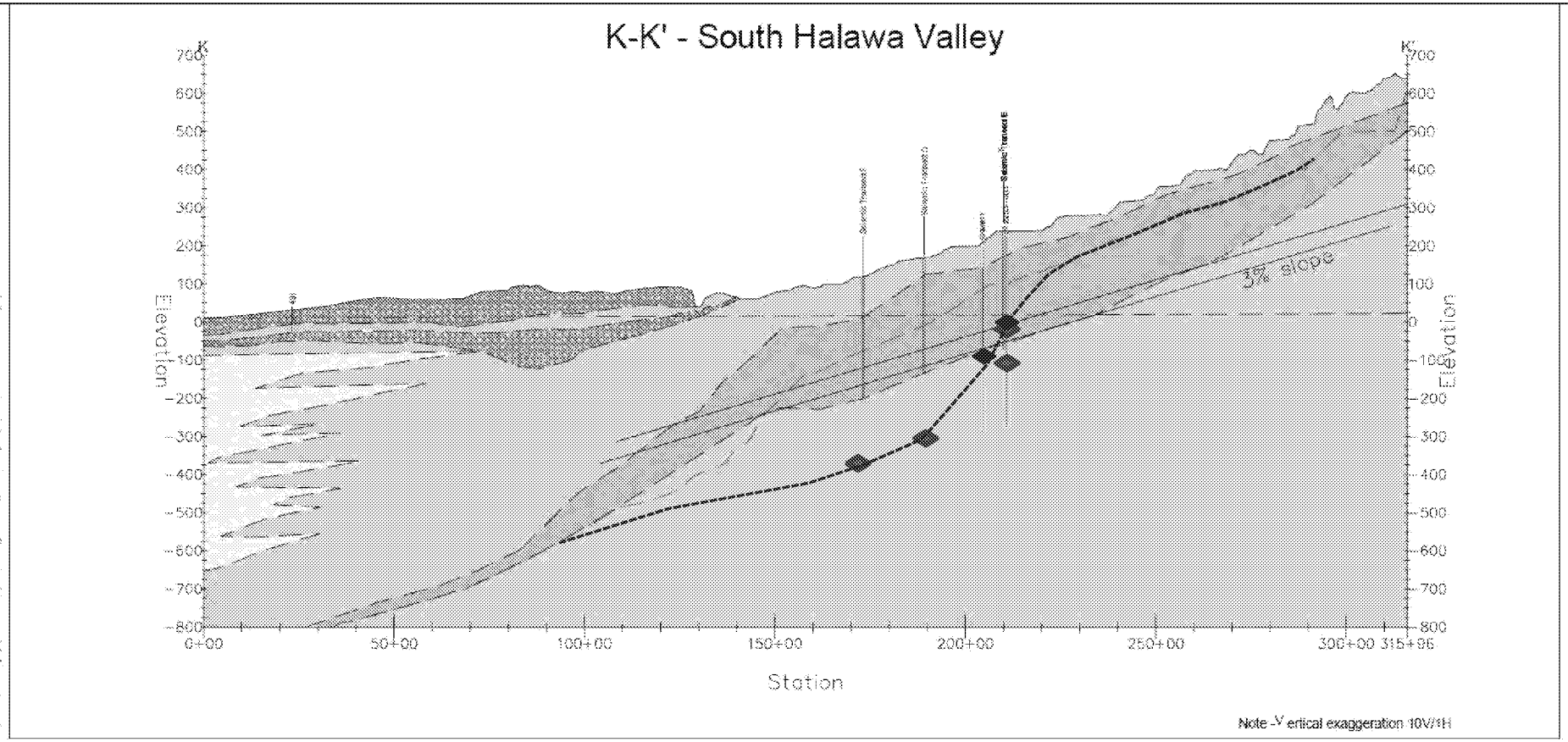
Measured and Modeled Parameters

- Groundwater Gradient
- Groundwater chemistry gradients
  - May indicate groundwater flow to the northwest
- Geologic controls on groundwater flow

Geologic Controls on Groundwater Flow

- Saprolite extent
  - South Halawa Valley longitudinal cross-section

Geologic Barriers - Saprolite



- Saprolite/Basalt interface based on Seismic Survey
- Saprolite/Basalt interface based on rock cores

LEGEND

Alluvium	Basal Groundwater (approximate)	Top of Basalt (Izuka et al)
Saprolite	Marine Deposits	Geologic Contact (approximate)
Basalt	Honolulu Volcanics - Tuff	

Conclusions and Closing Thoughts

- DOH recognizes that an incredible amount of work has been put into the Red Hill investigation
- Also a large amount of high quality data has been collected by the Navy's team
- DOH is not convinced that there are high rates of mauka to makai groundwater flow beneath the Facility
- Northwest groundwater flow, particularly in the upper part of the facility needs serious consideration

Department of Health
Red Hill Geology/Hydrogeology – Joint Agency Groundwater Investigations

Overview

- Logic for conducting these investigations
- Planned work
- Summary

Logic for Conducting These Investigations

- Cost effectively add to the body of knowledge of Red Hill geology/hydrogeology
- Increase the level of partnership between UH, USGS, and DOH
- To fulfill its regulatory obligations DOH needs to better understand groundwater flow and contaminant transport in the Red Hill area (and Statewide)
- This team has extensive experience in these investigations

Planned Work

- Characterizing the fluid transport properties of southeast Oahu basalts
- Borehole groundwater flow vector analysis
- Vertical profiling of Red Hill monitoring wells
  - Temperature
  - Specific conductivity
  - Petroleum related hydrocarbons

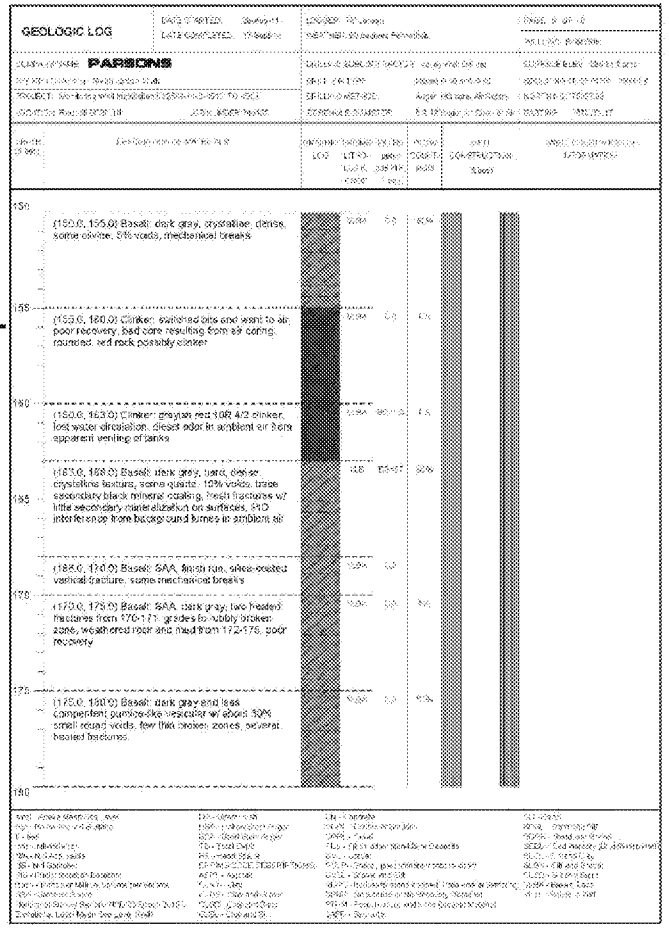
Characterizing the fluid transport properties of southeast Oahu basalts

- Partnership between DOH and UH Dept. of Earth Sciences
  - Dr. Scott Rowland – Lead Investigator
- Intent – to characterize the type, frequency, and distribution of the geologic structures that affect fluid (water and fuel) transport
- Apply to both vadose and saturated zones
- Tasks
  - Review of geologic data collected for Red Hill
  - Field surveys of the lava flow geometry and fabric
  - Design and execute fluid transport experiments
  - In the planning process

Conceptual Site Model, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility
JOINT BASE PEARL HARBOR-HICKAM, O'AHU, HAWAI'I

Administrative Order on Consent in the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket Number RCRA 7003-R9-2015-01 and DOH Docket Number 15-UST-EA-01, Attachment A, Statement of Work Section 6.2, Section 7.3.2, Section 7.2.2, and Section 7.3.2

June 30, 2019
Revision 01

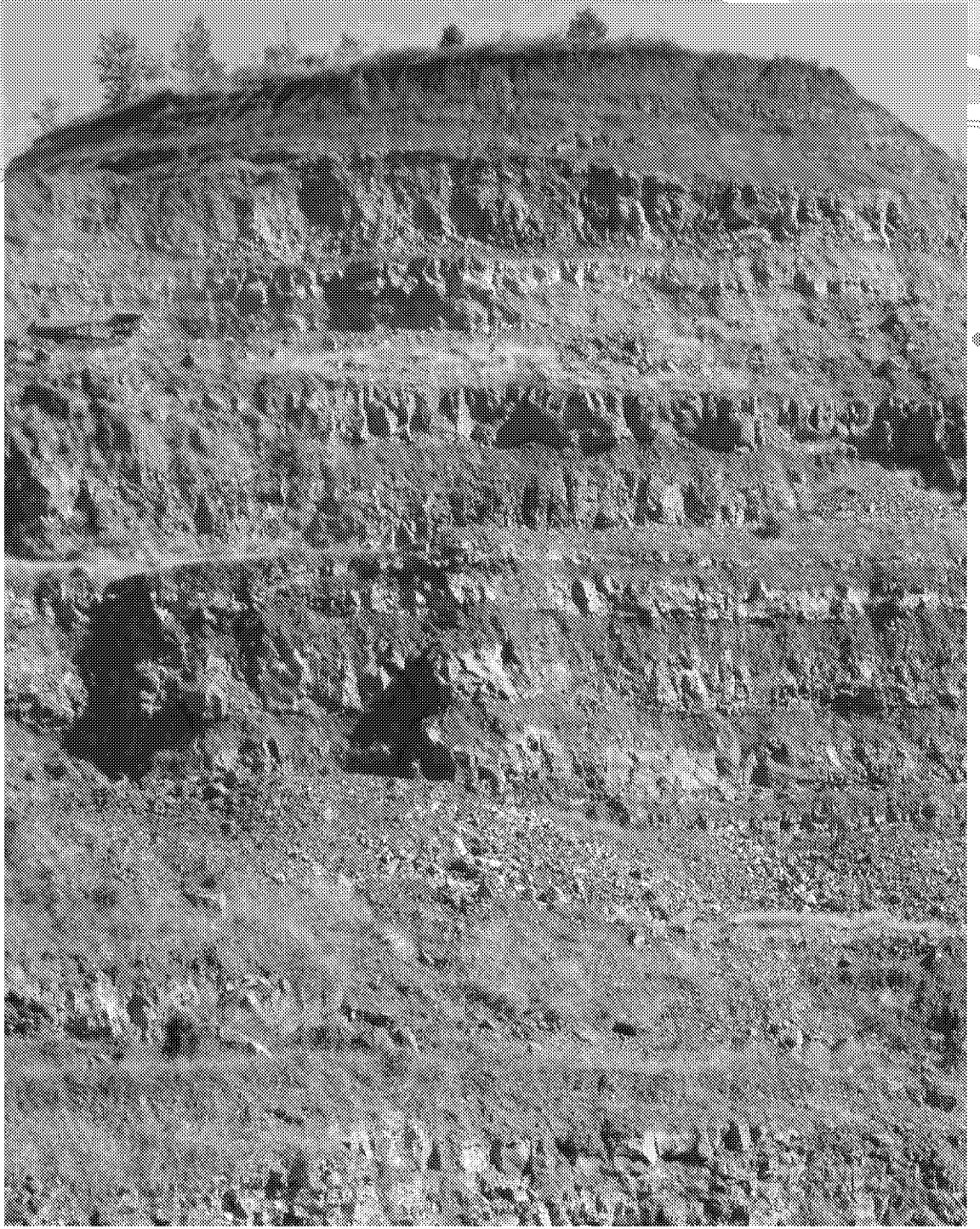


Geologic Controls on Fluid Transport Beneath the Red Hill Fuel Storage Tanks

- Review geologic data collected for Red Hill
  - Review reports,
  - boring logs, and
  - Inspect cores

RHMW06 CORE PHOTOGRAPHS

Core Interval 150 – 160 ft bgs



Geologic Controls on Fluid Transport Beneath the Red Hill Fuel Storage Tanks

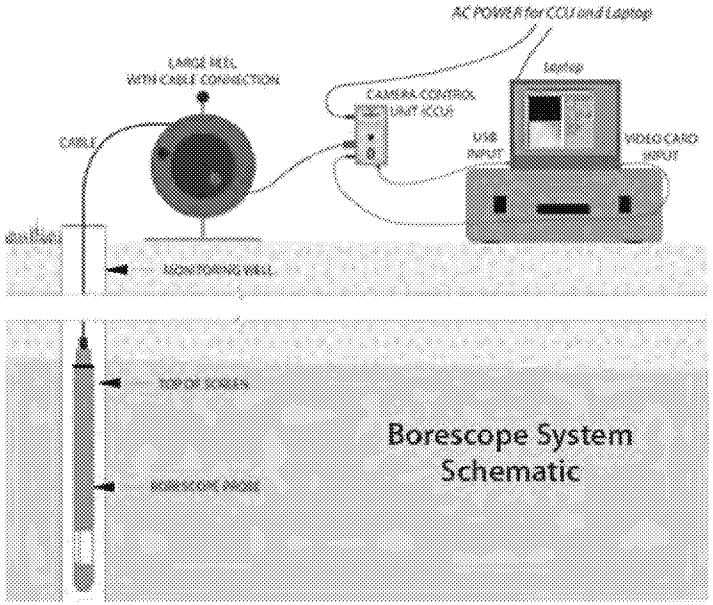
- Lava flow geometry
  - Detailed mapping of outcrops at the Halawa Quarry
  - To the extent access is granted map outcrops on Red Hill Ridge
  - To the extent possible map outcrops on the scale of UST Facility
  - Parameters:
    - Lava flow dip and azimuth
    - Flow type
    - Flow thickness

Geologic Controls on Fluid Transport Beneath the Red Hill Fuel Storage Tanks

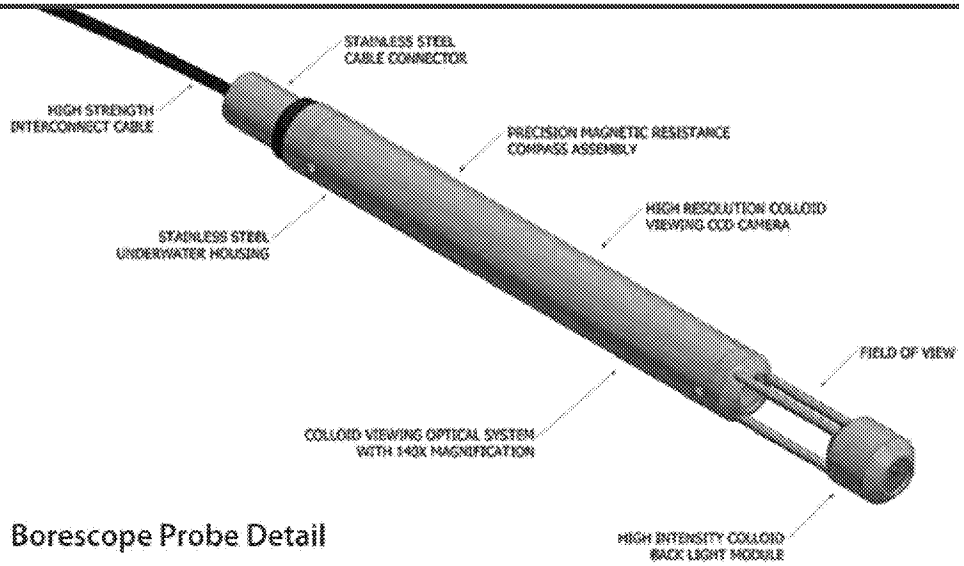
- Geologic fabric affecting fluid transport
  - Rock and fabric distribution and frequency
  - For example
    - Clinkers
    - Inter flow voids
    - fractures
- Survey
  - Halawa Quarry
  - If access granted, HBWS Moanalua Tunnel
    - Inspect fractures under lithologic stress
  - Other outcrops of opportunity

Measure Groundwater Flow Vectors in Selected Wells

- Colloidal Borescope
- Hawaii specific example
- Expected findings



Borescope System Schematic

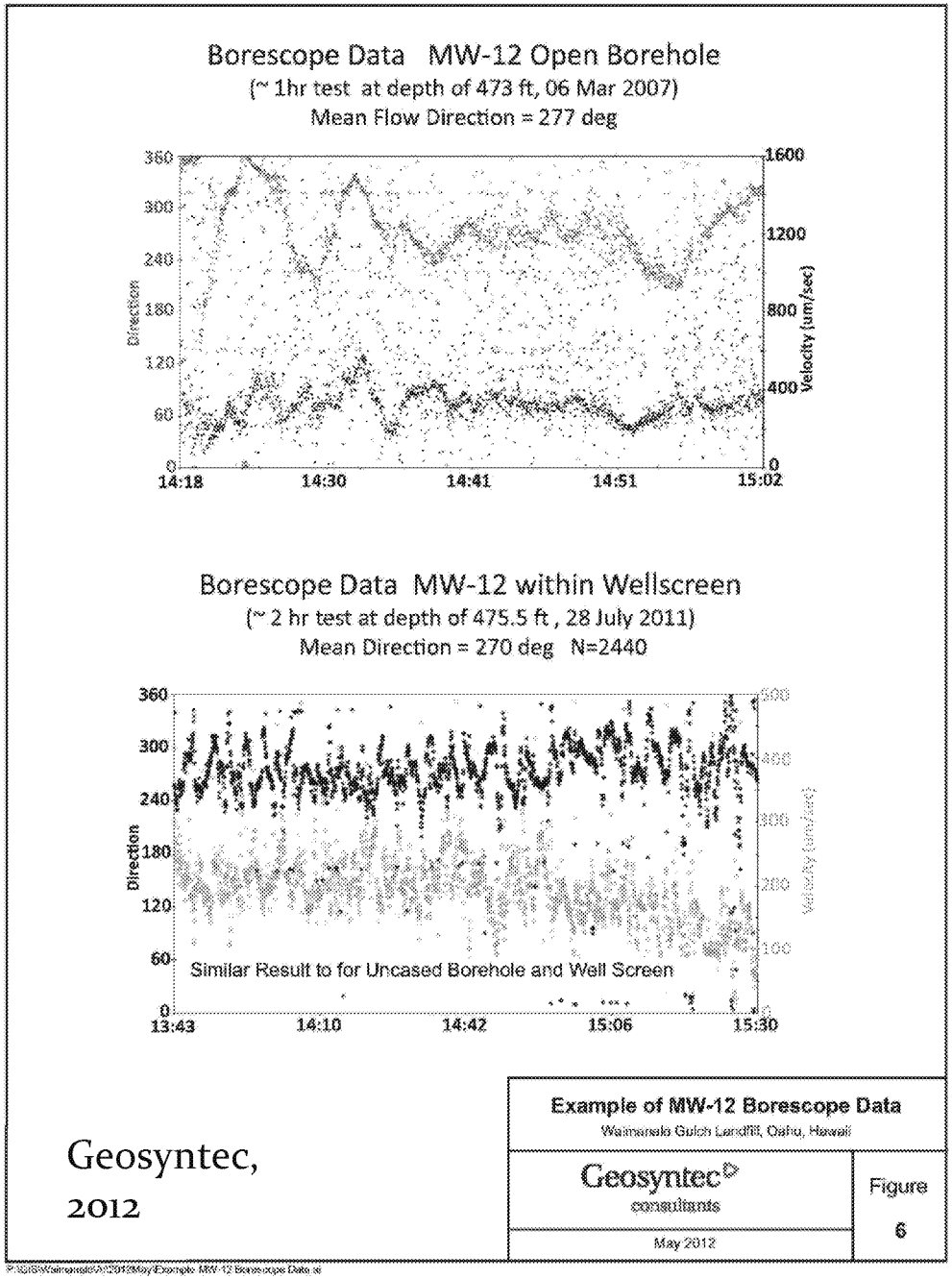


Borescope Probe Detail

Geotech Environmental Equipment, Inc.
2650 East 40th Avenue • Denver, Colorado 80205
(303) 320-4764 • **(800) 833-7958** • FAX (303) 322-7242
email: sales@geotechenv.com website: www.geotechenv.com

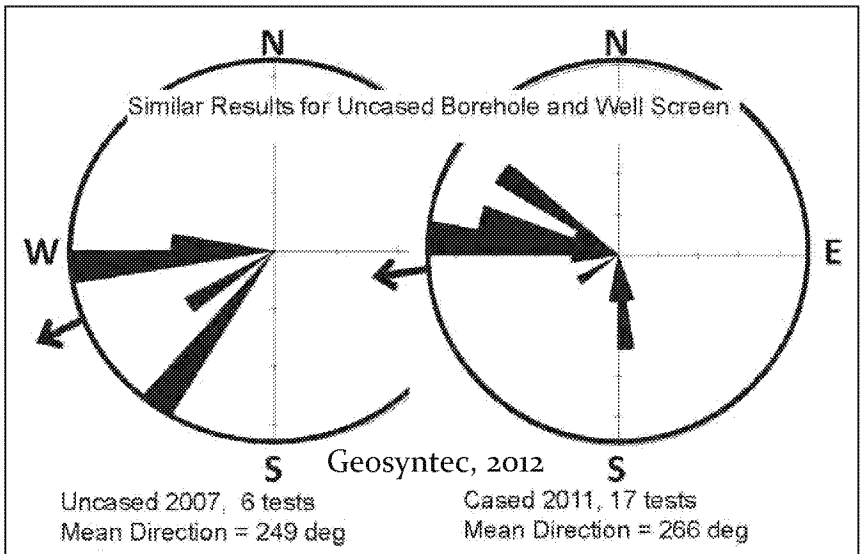
Colloidal Borescope Survey

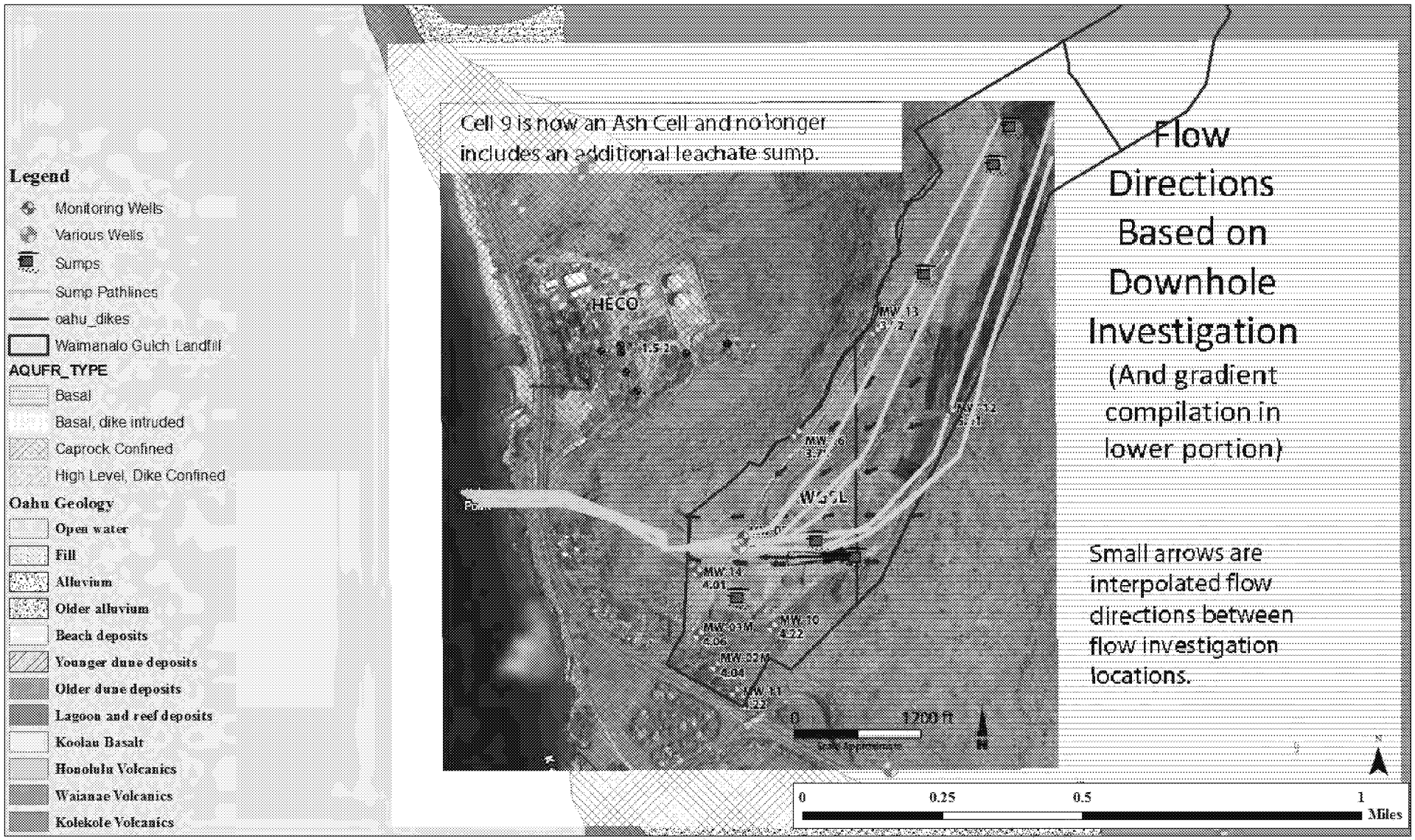
- Get point velocity vectors for groundwater flow in the Red Hill Groundwater Monitoring Network
- Test wells under differing pumping conditions
- Will begin to provide field data that support - or refute - basic parameters underlying the CSM and groundwater flow model
- Still in the planning process



Colloidal Borescope

- Provide time series data
  - Particle velocity
  - Azimuth of travel
- Can be done
  - Different depths in well
  - Under different pumping conditions
- Produce vector frequency plot





MODPATH tracks overlain on a map of Waimanalo Gulch Landfill showing groundwater flow vectors measured with a downhole borescope (blue arrows). Both the borescope (Blue vectors and arrows) and the MODPATH particle tracks (green lines) show close agreement. The background map is taken from slide 9 of a presentation to DOH by AECOM on 9/26/13.

Colloidal Borescope Survey – Expected Findings

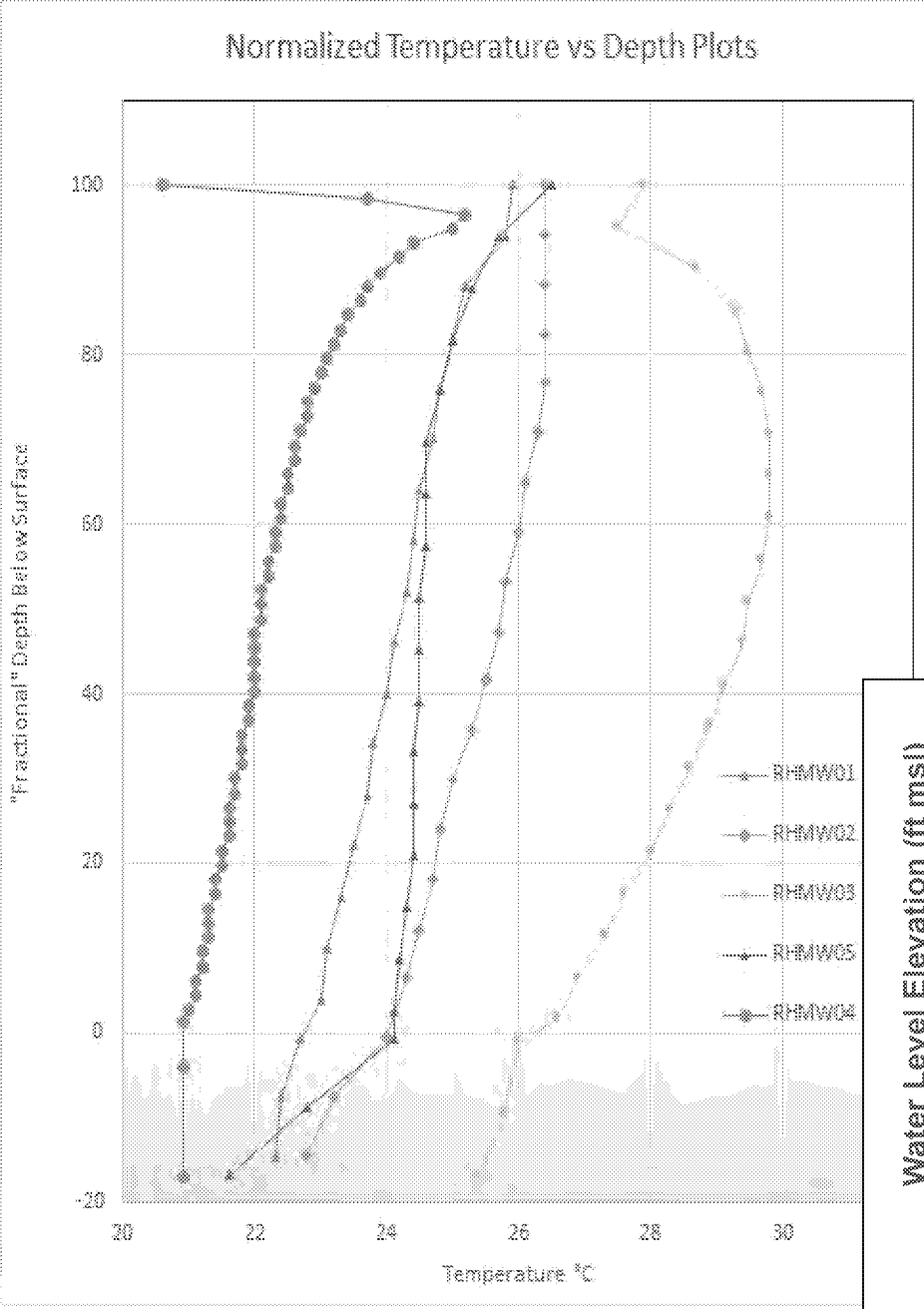
- Groundwater velocity vectors in selected wells under differing pumping conditions
  - Key wells
    - RHMW02 &03,
    - RHMW04,
    - RHMW05,
    - RHMW06, and
    - RHMW09
- Goals:
  - Develop flow field for groundwater beneath the facility
  - Get data to estimate borehole dilutions rates for tracer test design

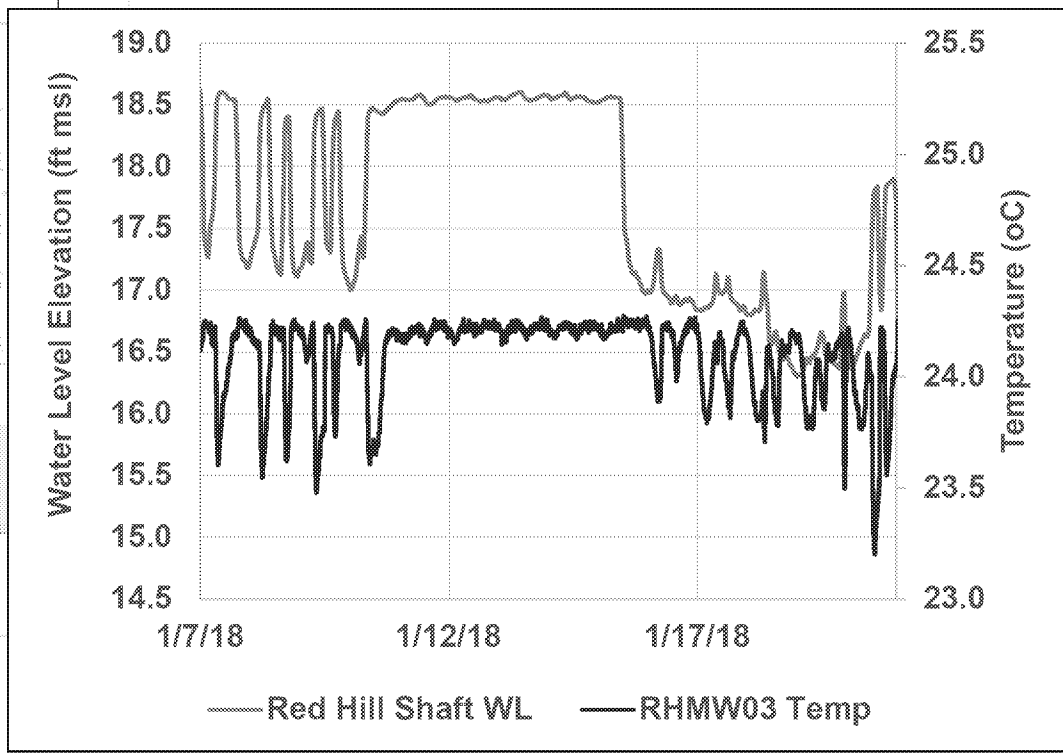
Vertical Profiling of Monitoring Well Temperature and Chemistry

- Vertical, conductivity, temperature, and depth survey
  - Various pumping conditions
- Depth specific sampling for selected petroleum constituents
- Questions to be answered
  - Is there stratification in the wells that needs to be considered?
  - Are there multiple entries in some of these wells that respond to differing pumping conditions and that could potentially affect our interpretation of regional groundwater flow?

Vertical Profiling of Selected Wells

- Distinct Differences in water Temps. and Temp. gradients
- Steepest Gradient in RHMW05; milder in RHMW03
- Significant temperature changes at RHMW05 in response to Red Hill Shaft on/off

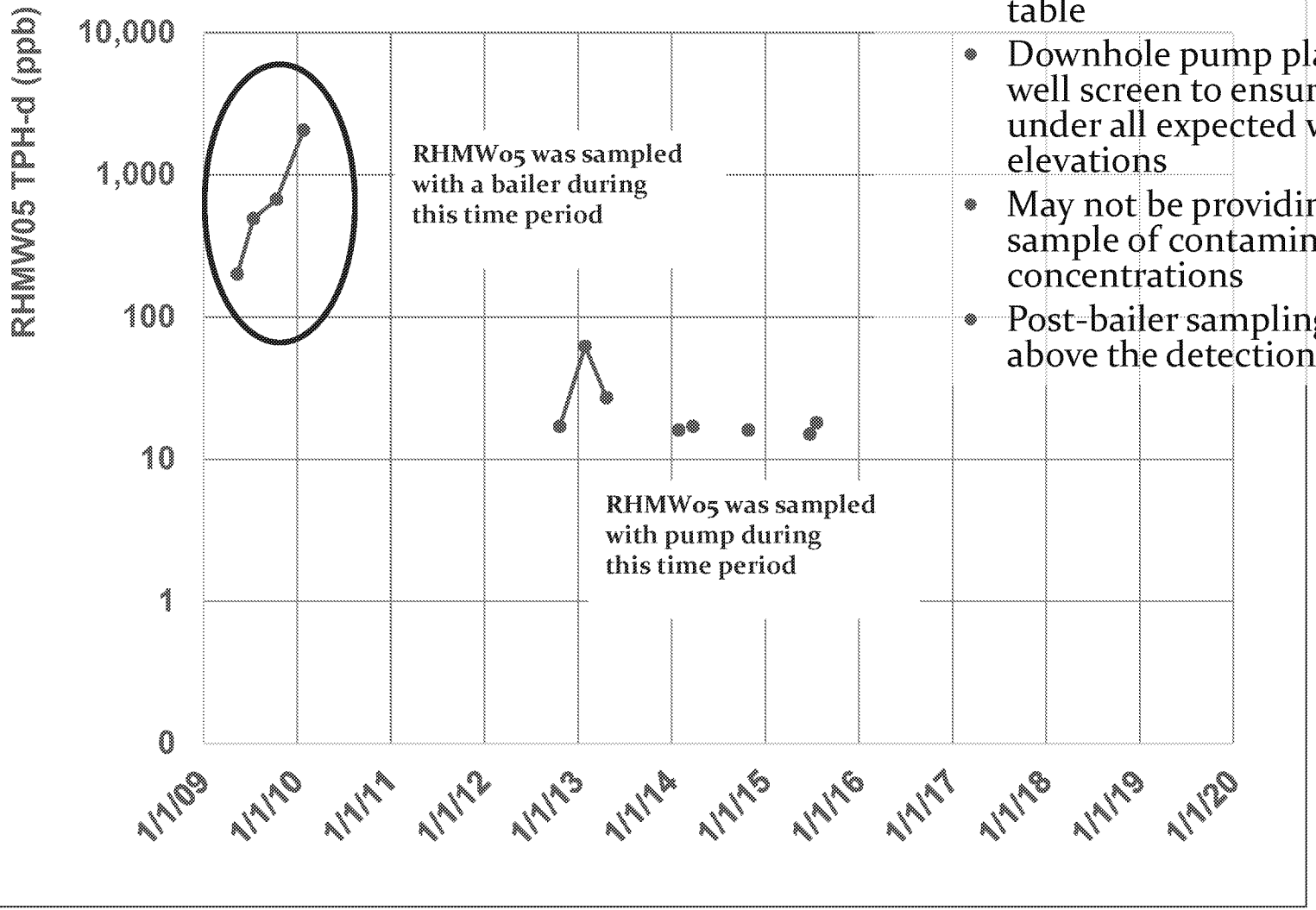




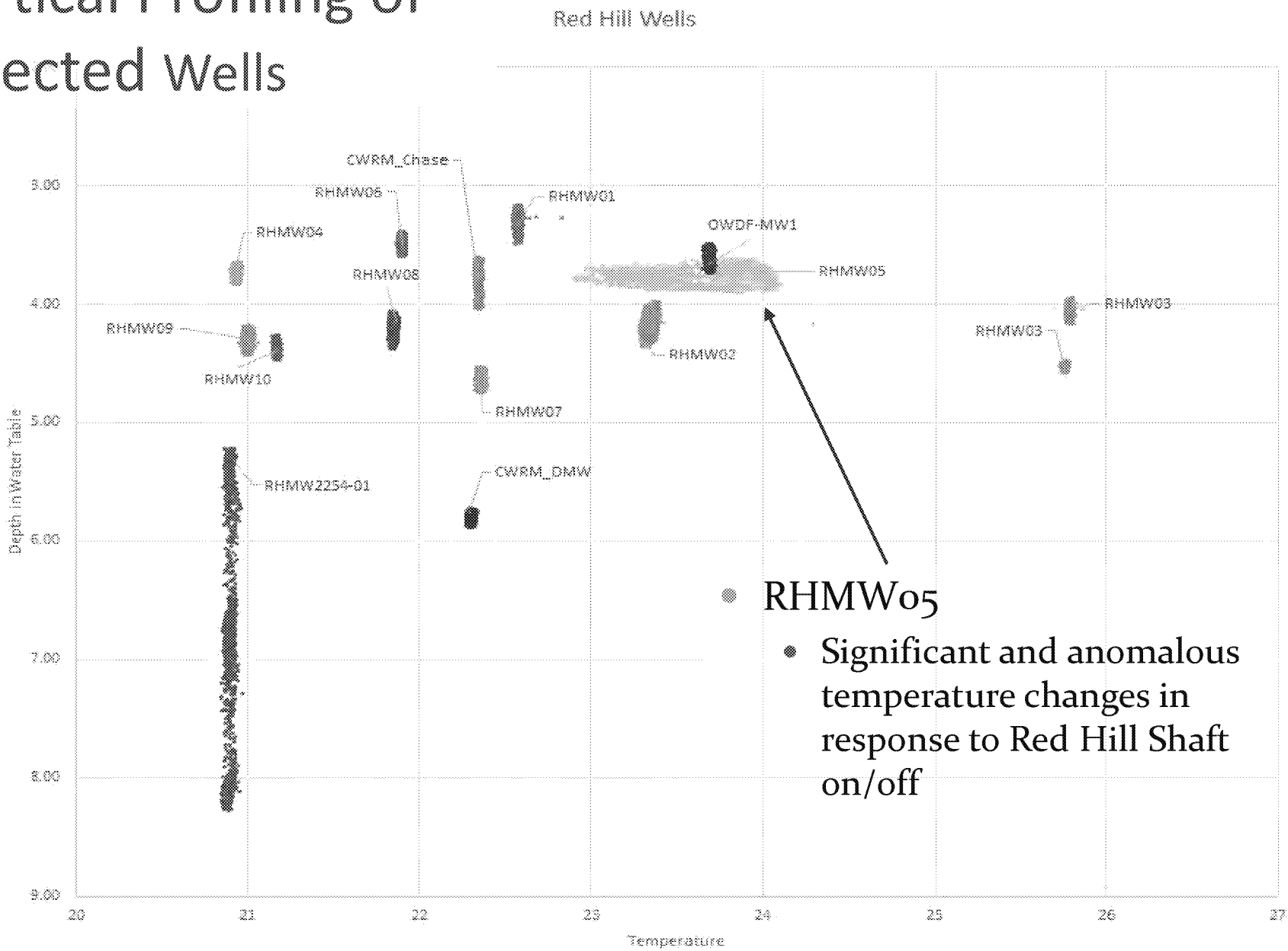
Vertical Profiling of Selected Wells

RHMW05

- Significantly elevated TPH when sampled at the water table
  - Bailer sampling targeted the water table
  - Downhole pump placed deeper in the well screen to ensure submergence under all expected water level elevations
  - May not be providing a representative sample of contaminant concentrations
  - Post-bailer sampling detections just above the detection limit



Vertical Profiling of Selected Wells



- RHMW05
  - Significant and anomalous temperature changes in response to Red Hill Shaft on/off

Summary

- There are substantial differences in the interpretation of available field data for the Red Hill Area
- These interpretations will underlie the risk analysis, and levels of computed risks, to Oahu's drinking water sources
- These differences, to a significant degree, are the result of a data set that is inadequate to definitively resolve rates and directions of groundwater flow
- The additional data provided by these studies are intended to help resolve critical questions regarding fate and transport of LNAPL and groundwater contaminants
- In the absence of definitive data on these questions, DOH is obliged to require the most conservative and protective measures available to protect Oahu's drinking water sources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Thank You!
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